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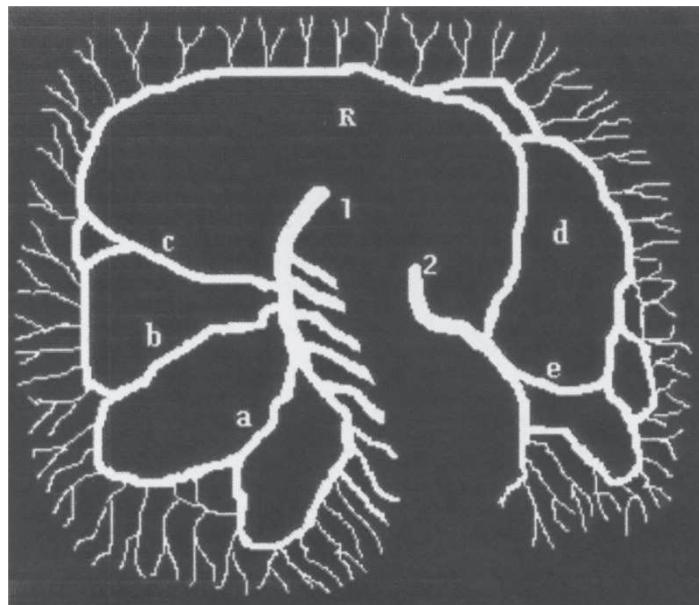
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# Esophageal Reconstruction with Large Intestine

## 1. Vascular anatomy of the colon

The colon is supplied with arterial blood from two main sources: the superior mesenteric artery (arteria mesenterica superior) and the inferior mesenteric artery (arteria mesenterica inferior). The right colon is supplied from the superior mesenteric artery through the following arteries: ileocolic artery (arteria ileo-colica), right colic artery (arteria colica dextra) and middle colic artery (arteria colica media). The inferior mesenteric artery supplies arterial blood to the left colon through the left colic artery (arteria colica sinistra). The ascending branch of the left colic artery (ramus ascendens) is joined with the middle colic artery by the arc of Riolan, creating in this way a connection between branches of inferior and superior mesenteric artery ( Fig. 1, 2).

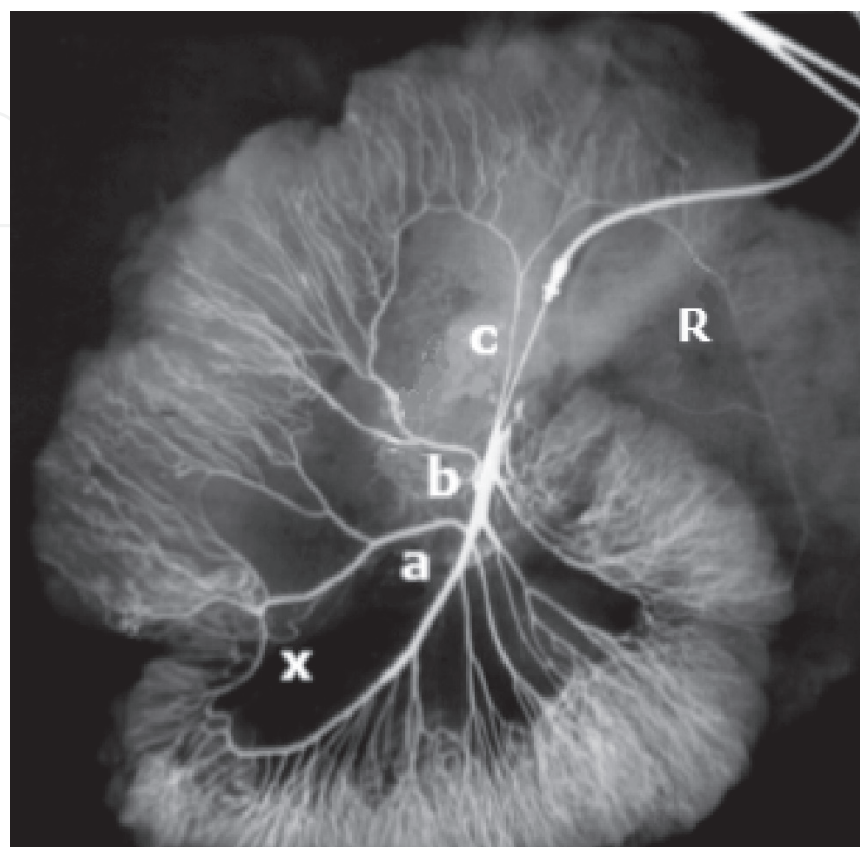


**Figure 1** Diagram of the arterial blood supply to the colon: 1 –art. mesenterica superior, 2 – art. mesenterica inferior, a – art. ileocolica, b – art. colica dextra, c – art. colica media, d – ramus ascendens art. colicae sinistrae, e – ramus descendens art. colicae sinistrae, R – arcus Riolani

Individual vascular trunks of the right as well as of the left colon interconnect forming so-called arcades. The arc of Riolan, the longest vascular arcade, also known as the marginal artery, connects the blood vessels on the right and left part of the colon.

It is worth reminding that the ileocolic artery, the right colic artery and the left colic artery are situated behind the peritoneum, while the middle colic artery, arising from beneath the lower border of the pancreas, passes between the layers of the transverse mesocolon and directs to the hepatic flexure of the colon. Recollection of these well known anatomical facts is inasmuch significant as during preliminary intraoperative evaluation of the type of colon vasculature, it turns out that only

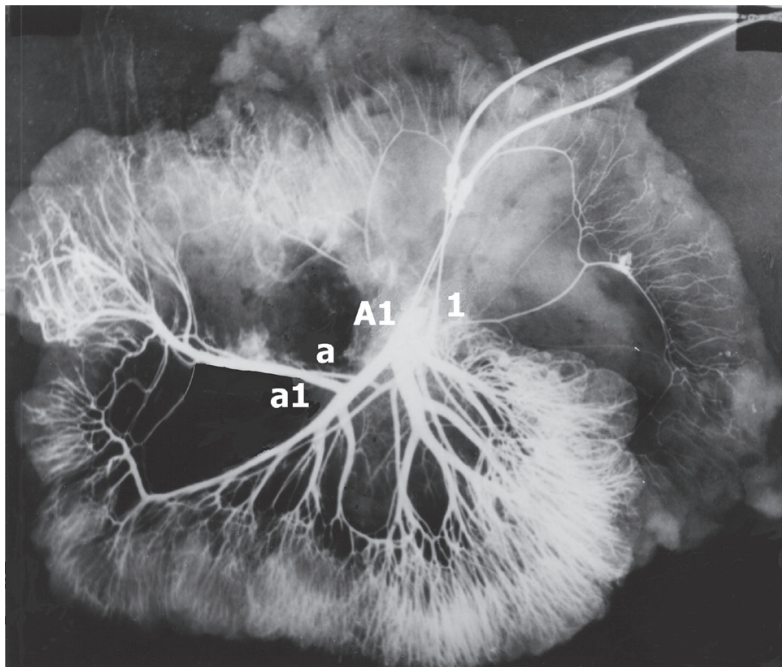
mobilization of the ascending and the descending colon exposes clearly enough the topography of main vascular trunks and anastomoses between them, what in turn affects significantly the choice of adequately supplied and long colon segment for esophageal reconstruction. Topography of the venous drainage mirrors the arterial supply, i.e. arteries have respective vein equivalents.



**Figure 2** Angiogram of the superior mesenteric artery and its branches: X – the iliac branch of the ileocolic artery, a – art. ileocolica, b – art. colica dextra, c – art. colica media, R- arcus Rioli

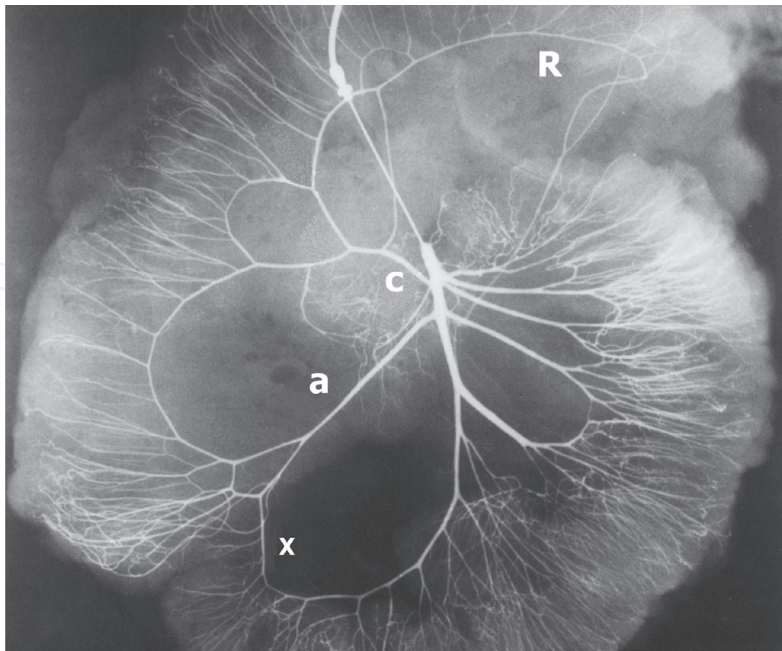
The above vascular anatomy of the colon is what we can read in human anatomy textbooks. In clinical practice we meet certain deviations from the above presented topography. They usually concern the right colon and the venous system (Fig. 3).

Own experimental studies as well as studies by other authors on intestinal preparations demonstrate that 6% of population present with lack or hypoplasia of arcades anastomosing the main venous trunks with simultaneously well developed arterial trunks and broad and well developed arterial arcades within the right colon. In such cases the right colon cannot be used for reconstruction due to inadequate venous system. Angiographic evaluations of the colonic arterial system reveal that permanent arteries present in 100% of population include the ileocolic artery, the middle colic artery and the left colic artery. Well developed arc of Rioli is met in 90% of population, and about 50% have good anastomoses between all colic arteries. The right colic artery is absent in about 30-35% of population (Fig. 4). In 25% of population, its absence is compensated for by 1 to 3 so-called additional middle colic arteries. However the arteries are usually short, with a narrow lumen and the anastomosing arcades are also short and narrow.



**Figure 3** Angiogram of the superior mesenteric vessels: 1 – art. mesenterica superior, A1 – vena mesenterica superior, a – art. ileocolica, well developed, with efficient anastomosing arcades, a1 – vena ileocolica with bushy branches, does not form anastomosing arcades

The above presented anatomical details of the arterial and venous vasculature of the colon are very important, as they play a crucial role in the choice of an adequate, i.e. with good arterial supply and efficient venous drainage, intestinal segment to form a pedicled graft of the colon.



**Figure 4** Angiogram of the superior mesenteric artery and its branches: X – the iliac branch of the ileocolic artery, a – art. ileocolica, c – art. colica media; absent art. colica dextra, R – arcus Rioli



## 2. Esophageal reconstructions using the colon

In order to organize and clarify descriptions of individual types of esophageal reconstructions, it should be remembered, as mentioned previously, that the main and at the same time permanent vessels of the colon include the ileocolic, middle colic and left colic vessels.

So-called adequate vascular systems in the aspect of reconstruction include long vascular trunks, which form wide arches passing into well developed and strong anastomosing arcades. The connection between the branches of the inferior and superior mesentery arteries, known as the arc of Riolan, is well developed. Such a situation gives the possibility of choosing either right, or left part of the colon to form a pedicled graft. For esophageal reconstruction each of the above mentioned colic vessels may be used to mobilize grafts in two positions: the isoperistaltic and the antiperistaltic grafts.

Selecting a segment of colon for esophageal reconstruction, one should always consider all the possibilities of the mobilization of the graft, in every individual case choosing the most suitable as far as blood supply and length is concerned pedicled segment of the colon. It should be remembered that the graft's length is strictly associated with the length of its vascular pedicle.

## 3. Esophageal reconstructions using the right colon

Taking advantage of an adequate vascular system in the colon, and choosing the right colon, the pedicled esophageal graft may be constructed using the following methods:

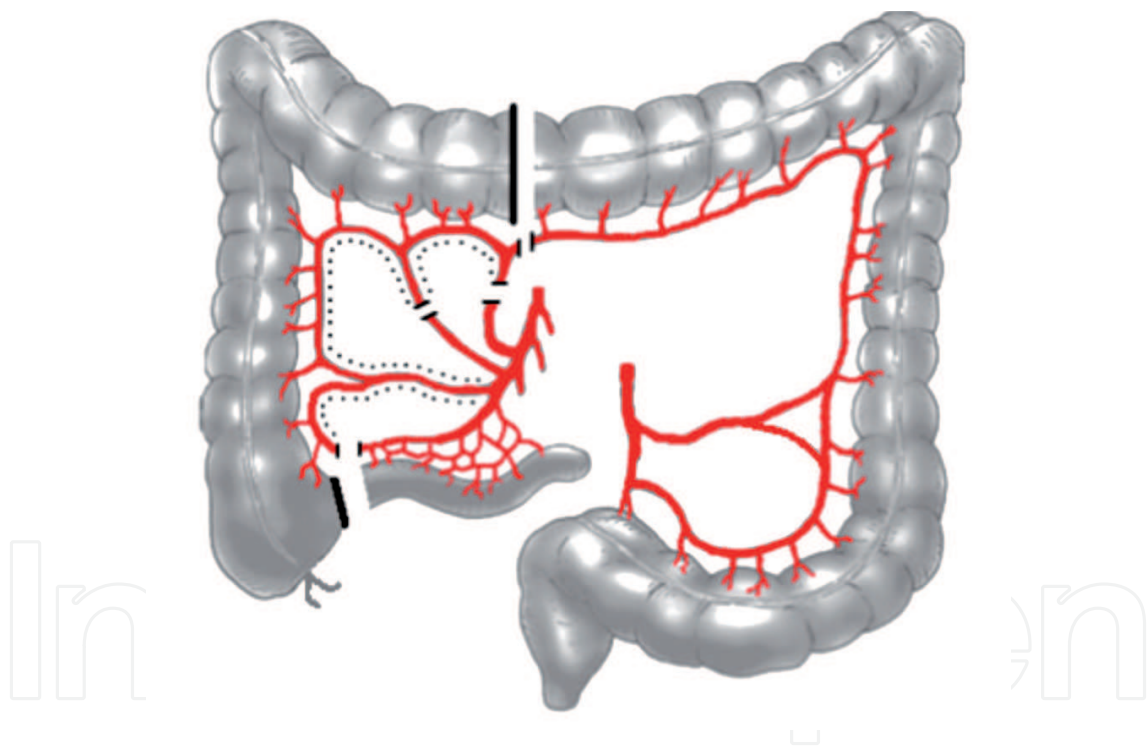
- from the right colon on ileocolic vascular pedicle in an antiperistaltic position of the graft
- from the right colon on middle colic vascular pedicle in an isoperistaltic position of the graft
- from the right colon on left colic vascular pedicle in an isoperistaltic position of the graft

### 3.1. The technique of creation of an antiperistaltic graft from the right colon on ileocolic vascular pedicle

The surgical technique presented below was developed by Prof. Jezioro in 1961 and used subsequently in the clinical practice in patients requiring esophageal reconstruction.

The abdominal cavity is approached from upper midline incision going several cm below and passing by the umbilicus on the right side. Next the right colon and the terminal segment of the ileum are mobilized. For this reason the small bowel loops are moved leftwards and maintained in this position with surgical towels. The parietal peritoneum is gradually transected starting

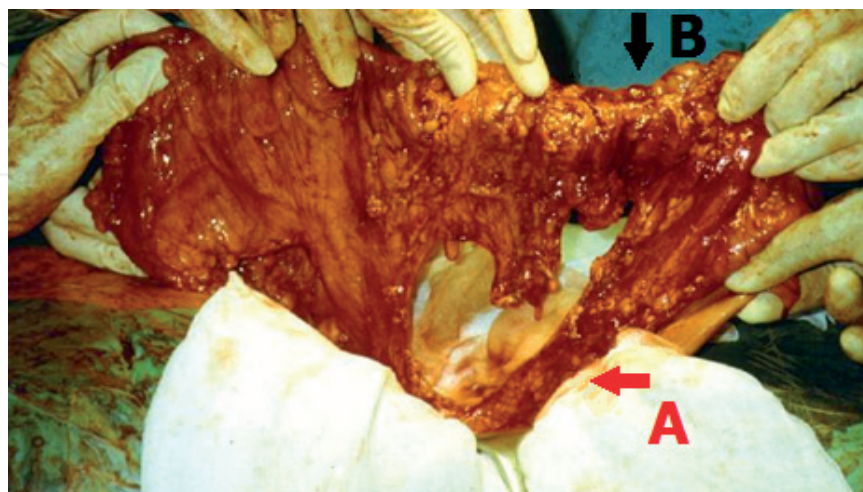
from the ileocolic region next to the large bowel and continuing until the right flexure of the colon. Next, slightly elevating the bowel, the caecum and the ascending colon are separated together with blood vessels, and the ligaments of the right flexure of the colon are exposed and transected between ligatures. This maneuver allows to identify macroscopically and evaluate the structure and efficacy of the vascular system in this part of the colon in the aspect of esophageal reconstruction. The adequacy of circulation is ascertained when the arterial and venous trunks of the ileocolic vessels are long and well developed and the arcades anastomosing them to the right colon vessels, i.e. the right colic vessels and the latter and middle colic vessels are long and broad. If the right colic vessels are missing, they can be replaced by middle colic vessels. Next a biological trial is performed, i.e. the trunks of the right and middle colic vessels, iliac branch of the ileocolic vessels and the vascular arch between the middle colic vessels and the left colic vessels are clamped with vascular clamps, in order to create conditions resembling those in a graft pedicled exclusively on ileocolic vessels. The trial is considered positive when the separated intestinal segment maintains normal colour and reveals pulsation in the terminal intestinal vessels close to the intestinal wall. The evaluation of blood supply to the isolated intestinal segment may be confirmed by intraoperative ultrasound examination.



**Figure 5** Diagram illustrating mobilization of a graft from the right colon on ileocolic vessels pedicle in an antiperistaltic position

Having evaluated the blood supply, with a positive outcome of the trial, the graft mobilization may start (Fig. 5, 6). The greater omentum is mobilized from the transverse colon to the middle of its length. Next the trunks of the right and middle colic vessels are ligated and transected. The transverse colon should be transected in the middle its length. The efferent transverse colon stump is sutured with a double-layer manual suture, or stapled. The vermiform appendix is

excised in a routine manner. Subsequently, the iliac branch of the ileocolic vessels and terminal vessels of the caecal segment of the ileum are ligated and transected. The ileum is transected and the stumps are closed with a double-layer manual suture, or stapled. The caecal stump of the transected ileum should be short in order not to create a diverticular excess, what may have an unfavourable effect on subsequent function of the substitute esophagus.



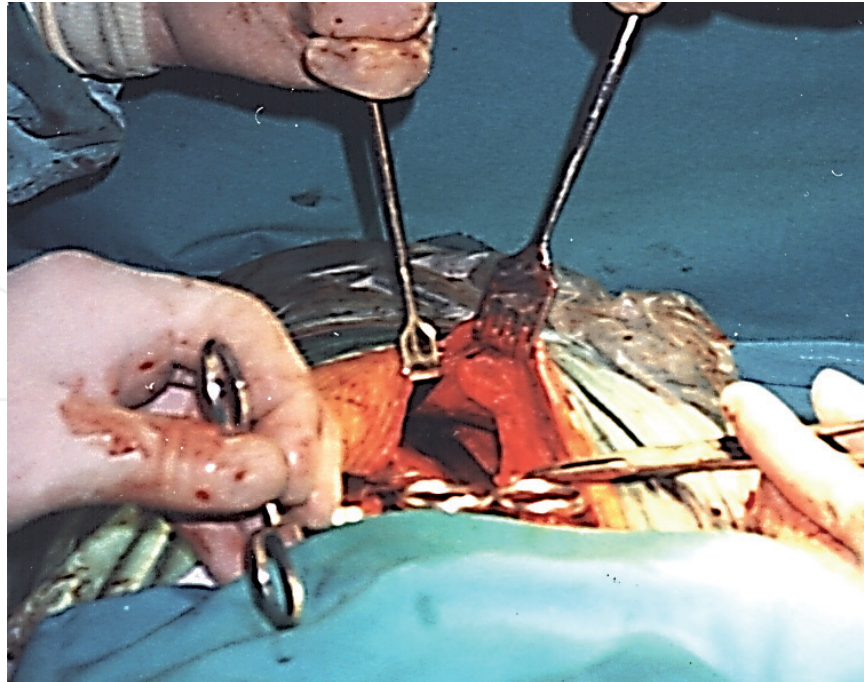
**Figure 6** Intraoperative picture of mobilization of the right colon graft on ileocolic pedicle in an anti-peristaltic position. A –vascular pedicle, B – right colon

Cephalic stump of the graft, which is formed by the right transverse colon, is also closed with a double-layer manual suture, or stapled. In this way the stage of mobilization of the graft from the right colon on an ileocolic vascular pedicle is completed. Thus the reconstruction is antiperistaltic – the cephalic segment of the graft from the right colon will be anastomosed with the cervical esophagus, and the caecum – with the stomach.

The next stage includes construction of a retrosternal canal and passing the graft through a canal created in the interior mediastinum to the neck. Construction of the retrosternal canal requires special precision. This procedure should be initiated from the abdominal side in the following way. The xiphoid process of the sternum is exposed. Next the parietal peritoneum is separated from the diaphragm and the straight abdominal muscles and their origins are detached from the xiphoid process and the region of costal angles. Sharp retractors are placed onto the prepared costal arches and used to elevate the sternum (Fig. 7).

Preparing gently under visual control, and in close proximity to the posterior surface of the sternum, the pericardium and pleural layers should be mobilized to the level of mid-sternum. Then the canal should be widened to the sides and upwards to the neck, what requires special precision and carefulness. The canal is widened with the use of a metal spatula with a rounded tip, 3 cm wide and 30 cm long. Maneuvering gently the spatula under visual control, in close proximity to the posterior surface of the sternum, a wide retrosternal canal reaching the jugular notch of the episternum is constructed. Having completed the retrosternal canal from the abdominal side, the superior canal opening from the side of the neck should be formed.





**Figure 7** Intraoperative picture of retrosternal canal – image from the abdominal side

In case of patients with post-burn cicatricial stenosis of the thoracic esophagus, the cervical stage of the surgery is performed in the following way. The platysma muscle is exposed and transected with a skin incision on the left side of the neck, along and parallel to the anterior border of the sternocleidomastoid muscle, which is continued to the episternum. Next the left middle muscles of the neck (*musculus sternothyreoideus et sternohyoideus*) are exposed and transected at their sternal origin. In this way the left lobe of the thyroid gland is exposed. Further on, the loose connective tissue of the jugular fossa is dissected and, preparing gently along the lateral wall of the trachea, the anterior-medial border of the sternocleidomastoid muscle is exposed. The upper belly of the omohyoid muscle is transected at the level of the carotid artery triangle and the left superior and inferior thyroid vessels are mobilized. Ligation and transection of the superior and inferior thyroid vessels exposes the left-side wall of the pharynx and the cervical esophagus. When exposure of the pharynx is not necessary, it is enough to ligate and transect only the inferior thyroid vessels. Preparing gently in the tracheoesophageal sulcus below the larynx, the cervical esophagus is separated from the trachea. In order to facilitate the procedure, a rubber drain is placed onto the mobilized esophageal segment and, pulling slightly the drain, the whole cervical esophagus is exposed. Next traction sutures are placed in the lowest point of the cervical esophagus and the esophagus is transected transversely above the sutures. The distal stump of the esophagus supported on traction sutures is closed with a double-layer manual suture, or the whole procedure of transection and closure of the distal esophagus may be performed with the use of a surgical staple. The cervical esophagus, which is prepared for being anastomosed to the graft, is left covered with a sterile towel.

Next the retrosternal canal is opened from the side of the neck. The mediastinal adipose tissue should be dissected from the posterior surface of the sternum in the jugular fossa. Then, large



cervical vessels and pleural laminae are carefully mobilized from the posterior sternum and the sternoclavicular joints, especially on the left, thus creating a sufficiently wide opening to the retrosternal canal from the side of the neck. Now a retractor is placed from the side of the neck on the mobilized episternum, and the sternum is gently pulled upwards. At the same time another retractor is placed on the xiphoid process from the side of the abdominal cavity. Elevating gently the sternum upwards and moving from the side of the neck and the abdomen, the retrosternal canal is widened on the sides, producing a canal that is wide enough on its whole length to hold the graft together with the vascular pedicle without tension.



**Figure 8** Picture of a patient after resection of thoracic oesophagus due to squamous cell oesophageal cancer (condition prior to oesophageal reconstruction).

on the neck – salivary fistula of the cervical esophagus;  
on the right side of the chest – scar after thoracotomy;  
in the epigastric midline – scar after laparotomy;  
in the left hypochondrium – feeding gastric fistula

The next stage consists in placing the graft, which was formed during the abdominal stage of the operation, in the prepared retrosternal canal. For this reason, holding both previously placed retractors which elevate the sternum upwards, a thick long drain is inserted to the canal from the side of the neck, one arm of the drain leading from the canal to the epigastrium, the other being maintained on the neck. In order to shorten the graft's route, a colon segment mobilized on a vascular pedicle is passed beyond the stomach through an adequately wide slit, created in the hepatogastric ligament before it is placed in the retrosternal canal. The cephalic segment of the graft is fastened to the drain from the side of the abdomen. Gently pulling the drain's arm protruding from the side of the neck, the graft is pulled through the retrosternal canal and its cephalic part is exposed onto the neck in such a way as to enable its tensionless anastomosis to the cervical esophagus. Now the sternum-elevating retractors are removed. In this way the graft is positioned in the retrosternal canal. The part of the

right colon which forms the cephalic segment of the graft is situated on the neck, while the caecum forming the caudal portion of the graft is anastomosed to the stomach. Thus constructed and placed in the retrosternal canal graft is arranged antiperistaltically. When the graft is left in the retrosternal canal, continuity of the gastrointestinal tract in the abdominal cavity should be restored, i.e. the ileum should be anastomosed to the distal part of the transverse colon. During this procedure the blood supply to the part of the graft emerging onto the neck should be monitored constantly. In case any features of ischemia appear in the graft segment emerging onto the neck, the graft must be immediately evacuated from the retrosternal canal and the cause of ischaemia removed. Only efficiently supplied graft authorizes its anastomosis to the cervical esophagus. Anastomosis of the caudal segment of the graft is performed in the prepyloric part of the stomach, what may prevent reflux of the gastric content to the replacement esophagus. Having performed all anastomoses within the abdominal cavity, the last stage of the reconstructive surgery may be performed – end-to-side anastomosis of the cervical esophagus with the lateral wall of the colon emerging onto the neck. The reconstructive surgery is finished when the abdominal integuments and the cervical integuments are closed.

In case of patients after resection of the thoracic esophagus due to cancer, the cervical stage of the surgery is slightly different than in individuals with post-burn cicatricial stenosis. In some patients resection of the thoracic portion of the esophagus due to cancer and reconstruction of the digestive tract continuity is performed in a single-stage operation. The excised esophagus is then replaced with the whole stomach, or a tube formed from the greater curvature of the stomach localized in the bed of the resected esophagus, i.e. in the posterior mediastinum. In patients, in whom single-stage esophageal reconstruction by means of stomach is not possible for various reasons, a reconstructive surgery with pedicled intestinal segment is considered. Due to a significant extent of the resection and reconstructive surgery, the procedure is performed in two stages. The first stage includes resection of the thoracic esophagus with lymphadenectomy, formation of a salivary fistula of the cervical esophagus, and a gastric or intestinal fistula for feeding the patient (Fig. 8). In the second stage, after several weeks, the retrosternal replacement esophagus is constructed with a pedicled colon segment. Mobilization of the pedicled colon segment, as well as creation of a retrosternal canal from the side of the abdomen is performed in the above-described manner, whereas opening of the retrosternal canal from the side of the neck is preceded by preparation of the salivary fistula and the cervical esophagus. The prepared segment of the cervical esophagus is covered with a surgical towel and placed on the upper border of the surgical wound on the neck. Opening of the retrosternal canal from the side of the neck is performed in the above-described way. When the retrosternal canal is wide enough from the side of the neck, as well as from the abdominal side, a mobilized pedicled colon segment is passed behind the sternum. Further procedures, i.e. restoration of the continuity of the gastrointestinal tract in the abdominal cavity, anastomosis of the caudal part of the graft with the stomach and anastomosis of the cephalic part of the graft with the cervical esophagus is performed in the same way as described in patients with post-burn cicatricial stenosis. In this group of patients the resection surgery is preceded by presurgical chemotherapy, or chemo- and radiotherapy. In some patients chemotherapy is administered as adjuvant therapy after resection of the esophagus and prior to reconstructive surgery. As the aim of the authors was to present only esophageal reconstructions with the use of pedicled intestinal segments, treatment of esophageal carcinoma will not be discussed in details.



**Figure 9** Radiogram of a replacement retrosternal oesophagus from the right colon on ileocolic vascular pedicle in an antiperistaltic position according to Jezioro

The above described modality of esophageal reconstruction is advantageous for a number of reasons. The operation is fairly simple technically, provided the vascular system in this part of the colon was evaluated accurately. Mobilization of the graft causes relatively small deficit of the intestine in the abdominal cavity. The graft, constructed according to the above-described method, is long enough, and may be anastomosed to the pharynx, for example in patients with obstructed cervical esophagus.

Theoretically, the only disadvantage of the reconstruction modality may be associated with an antiperistaltic position of the graft, although control studies in patients with antiperistaltic reconstructions did not confirm these fears (Fig. 9).

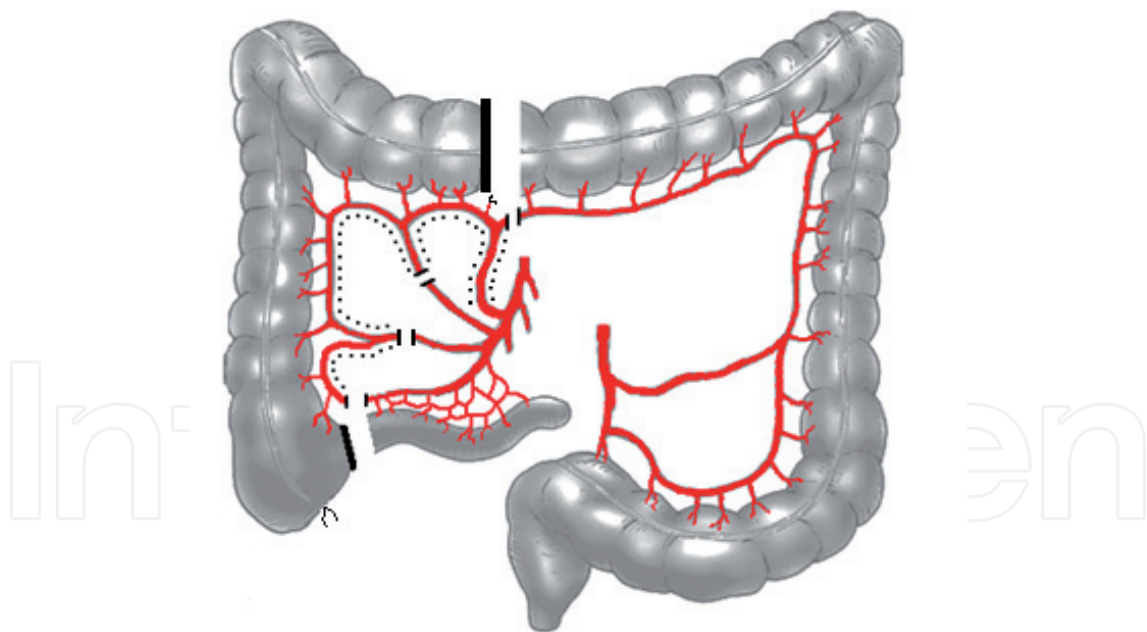
### **3.2. The technique of construction of an isoperistaltic graft from the right colon on middle colic vascular pedicle**

The right colon may be also used to isolate another kind – an isoperistaltic colon graft pedicled on the middle colic artery. This type of graft is conditioned by the presence of well developed, long main vascular trunks within the right colon, which are anastomosed with broad, well developed and efficient arcades. The surgical modality presents as follows.

The abdominal cavity is opened through an upper midline incision passing by the umbilicus and going 2-3 cm below. The next stage is to mobilize the right colon and the terminal segment of the ileum in a manner presented above, what enables macroscopic evaluation of the vascular system in this part of the colon. On finding a positive vascular structure, a biological trial should be performed, in which the trunks of the ileocolic and right colic vessels are clamped with vascular clamps, thus leaving the selected part of the colon supplied only by the middle colic vessels. It should be remembered that in some patients the right colic vessels are missing (see: Fig. 4), and the middle colic vessels are shaped in the form of two or three additional colic vessels. In such cases, with narrow arcades

joining the middle colic vessels and the additional middle colic vessels, the use of both middle colic trunks as the graft pedicle may be considered, provided the double pedicle does not shorten the length of the mobilized colon graft. Any disturbances in the blood supply to the graft, arterial or venous, observed during the biological trial, oblige to resign from this part of the colon and impose selection of another, adequately supplied, segment of the large intestine.

In case the result of the biological trial is positive and no disturbances in the blood supply to the isolated fragment of the colon are observed, mobilization of the graft may be initiated. First the greater omentum is removed in the area of the mobilized colon segment, and next the vascular trunks, which had been clamped in vascular clamps, are ligated and transected. In some cases the arterial trunk should be ligated separately from the venous trunk, as they are often distant and their jointly ligation may contribute to shortening of the vascular pedicle in the mobilized graft. Next the transverse colon should be transected in the middle of its length. The efferent stump of the transverse colon is closed with a double-layer manual suture, or stapled. On the other hand, the afferent stump, which forms the caudal segment of the mobilized graft, is closed with a temporary suture until it is anastomosed with the stomach. Transection of the ileum in the caecal region completes mobilization of the graft. The stumps of the transected ileum are closed with a double-layer manual suture, or stapled, close to the caecum, without leaving diverticular excess. Appendectomy is performed in a routine manner. The isoperistaltic graft from the right colon pedicled on the middle colic artery is thus constructed (Fig. 10).



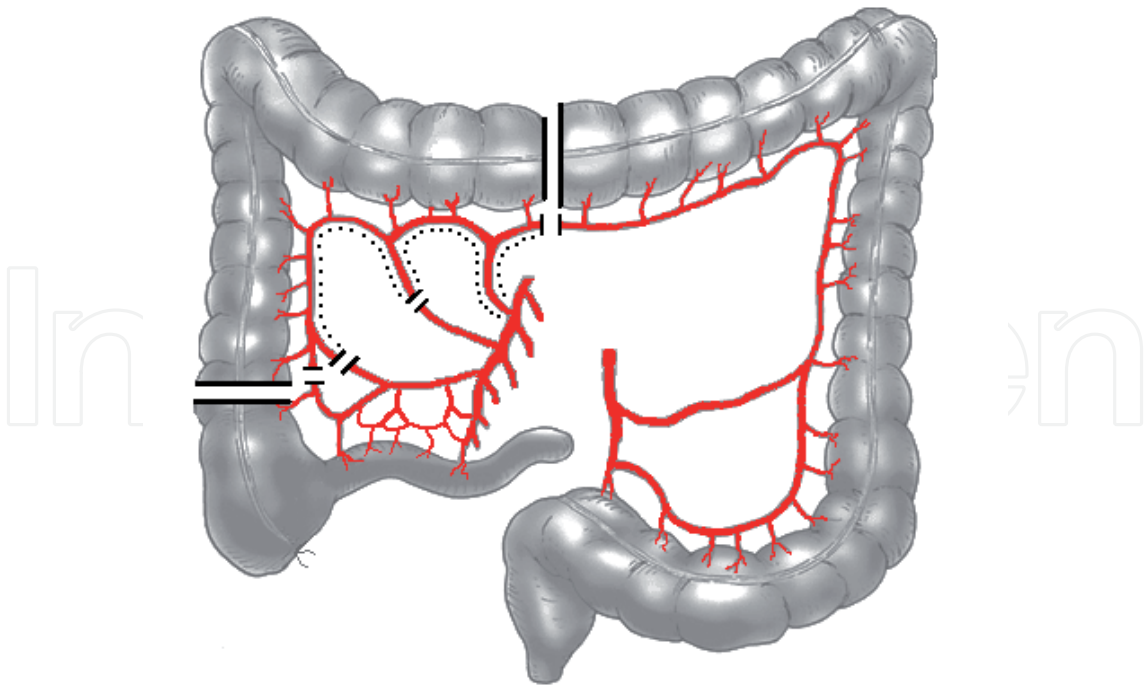
**Figure 10** Diagram of mobilization of a right colon graft together with the caecum on middle colic vascular pedicle in an isoperistaltic position

Further steps are similar to those presented above. They include construction of the retrosternal canal, placement of the graft in the canal, restoration of gastrointestinal continuity and anastomosing the graft with the stomach and the cervical esophagus.



The above-presented modality of esophageal reconstruction has many advantages. At the same time it is not free from certain disadvantages. The most significant advantages include an isoperistaltic position of the graft, what undoubtedly has a positive effect on its functioning as an esophageal replacement. Making a decision as to the choice of the above described reconstructive modality, it should be remembered that it is conditioned by the presence of an exceptionally effective vascular system within the right colon. In case additional middle colic vessels are present, they usually have relatively short trunks, and shorter and narrower anastomosing arcades, and for these reasons the mobilized graft may turn out to be too short to be anastomosed to the cervical esophagus. Another disadvantage is a large mass of the cephalic segment of the graft, i.e. the caecum, what may hamper safe passage of the graft through the superior opening of the retrosternal canal just beyond the left sternoclavicular joint. Pressure present in the region of the superior opening of the canal leads to irreversible ischemic changes and severe postsurgical complications, in form of necrosis of the cephalic segment of the graft. In order to prevent such complications, it is necessary to perform partial or complete removal of the joint, what is practiced in some surgical centres.

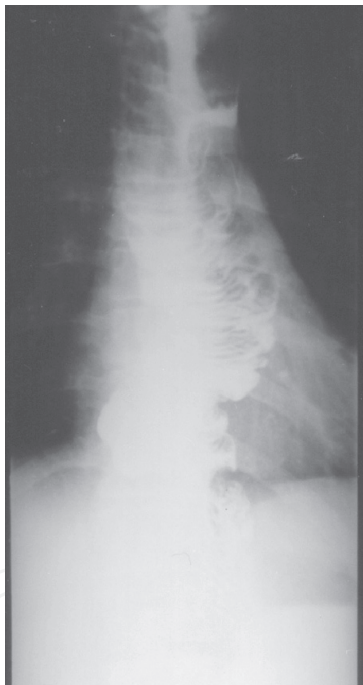
In cases, in which very long main vascular trunks in the right colon are found during the operation, and the anastomosing arcades are also long and wide, a similar graft may be constructed, but without participation of the caecum. Then slightly longer segment of the transverse colon should be mobilized. Such a variant of operation is possible when, apart from an adequate vascular system in the right colon, also the arc of Riolo is very well developed. In this way problems associated with the presence of the caecum, which forms the cephalic portion of the graft, may be avoided in some cases. Choosing this surgical modality, we obtain an isoperistaltic graft with a straight shape and significantly narrower diameter in the cephalic portion (Fig. 11).



**Figure 11** Diagram of mobilization of a right colon graft on middle colic vascular pedicle in an isoperistaltic position without the caecum

As it was described in the previous section, the next stage of the operation includes construction of the retrosternal canal and passage of the graft through the canal created in the anterior mediastinum. In order to obtain sufficient mobility of the graft, it is worth considering reducing the caudal portion of the intestinal segment which will be anastomosed to the stomach. The graft is then passed behind the stomach through a hole formed in the hepatogastric ligament and placed in the created retrosternal canal. The proximal segment of the graft, i.e. the caecum is exposed onto the neck, if the first variant of the reconstructive surgery was chosen. If mobilization of the graft was done according to the second variant, i.e. without participation of the caecum, the ascending colon is exposed on the neck. Anastomoses within the abdominal cavity restoring the gastrointestinal continuity as well as anastomosis of the caudal portion of the graft with the anterior wall of the prepyloric part of the stomach complete the abdominal stage of the reconstructive surgery. The last stage includes anastomosing the cervical esophagus to the lateral wall of the colon exposed to the neck. Suturing of the abdominal layers and the neck terminates the reconstructive surgery.

Remote follow up examinations in patients after reconstructive surgery performed according to the above described modality revealed efficient function of the replacement esophagus (Fig. 12, 13).



**Figure 12** Radiogram of a replacement retrosternal oesophagus from the right colon on middle colic vascular pedicle in an isoperistaltic position. A-P projection

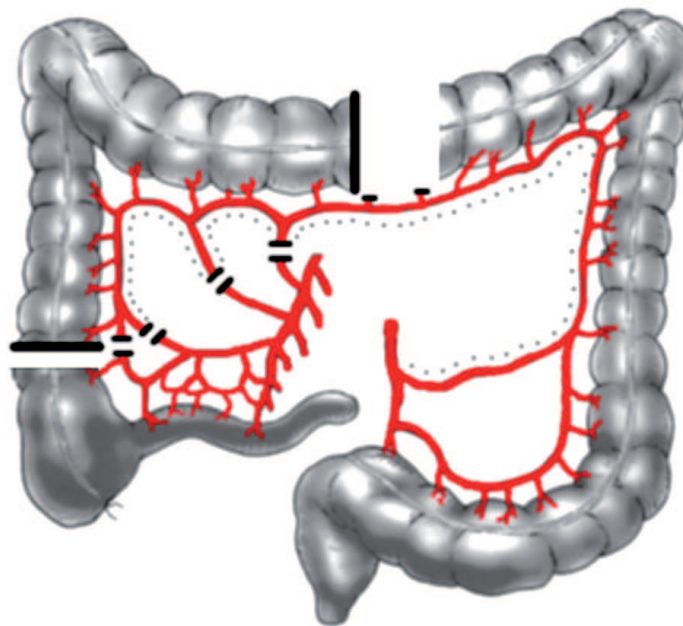


**Figure 13** Radiogram of a replacement retrosternal oesophagus from the right colon on middle colic vascular pedicle in an isoperistaltic position. Lateral projection

### 3.3. The technique of construction of an isoperistaltic graft from the right colon on left colic vascular pedicle

Construction of a graft pedicled on the left colic artery is another possibility of using the right colon for esophageal reconstruction. This variant of the reconstructive surgery is much more com-

plicated and requires excellent surgical technique as well as careful intraoperative evaluation of the colonic vasculature. This surgical modality may be used only when the right colonic as well as the left colonic circulation is highly adequate and the arc of Riolan is very well developed. The main advantage of this surgical modality is the possibility of obtaining a very long graft. The risks however concern the vascular pedicle. The graft is supplied from the left colic vessels, but the only, very long, route of blood supply to the whole graft is from the arc of Riolan. With an erroneous evaluation of the efficacy of the graft vasculature, this situation may lead to peripheral ischaemia of the mobilized segment of the colon. For this reason, when a decision is made to choose this reconstructive modality, the intraoperative biological trial of vascular efficiency should be meticulously performed and accurately evaluated.



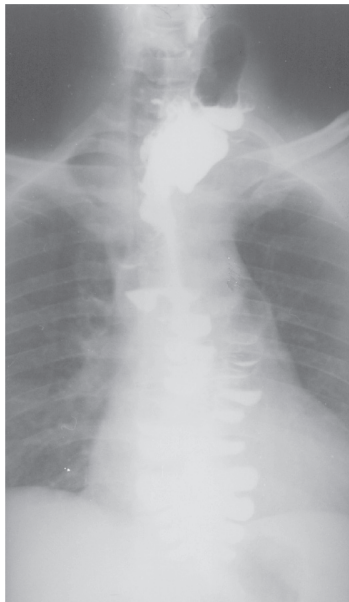
**Figure 14** Diagram of mobilization of a right colon graft on left colic vascular pedicle in an isoperistaltic position

Technically this modality is much more difficult than those previously described. After laparotomy it is necessary to mobilize the right colon. The greater omentum is separated from the transverse colon on its whole length. The result of the biological trial plays a decisive role. If, after clamping the trunks of the middle and right colic vessels and the arch joining the ileocolic vessels and the right colic vessels, the observed colon does not reveal any signs of ischaemia, further mobilization of the colonic segment may proceed. The left flexure of the colon and the descending colon should be mobilized. For this reason the small intestine loops are moved to the right side of the abdominal cavity and maintained in this position with surgical towels. The peritoneum is transected longitudinally on the external side of the descending colon as well as on the right side. Next, slightly elevating the colon, the descending colon is carefully separated together with its vessels and the left flexure of the colon is exposed. Ligaments supporting the flexure are cut between ligatures.

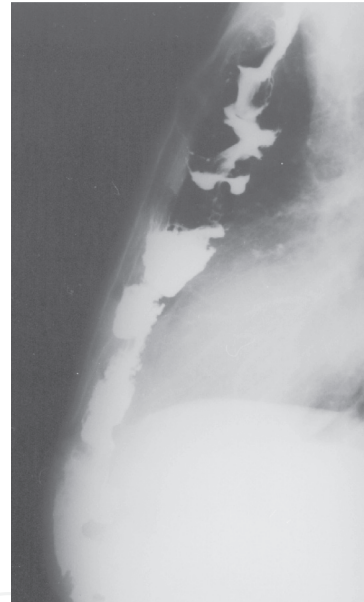
In the next stage of the surgery the vessels trunks which were previously clamped, i.e. the right colic, middle colic and the arches between the right colic and ileocolic vessels are ligated and transected. Also the ascending colon is transected at this level. Remembering that the graft has to

be long enough to reach the neck where it is anastomosed to the cervical esophagus, a longer or shorter segment of the transverse colon is selected and cut at this level. Reduction performed in the caudal portion of the graft permits to achieve its adequate mobility, and free from tension in the vascular pedicle translocation of thus mobilized graft beyond the stomach, and next, through the retrosternal canal, onto the neck (Fig. 14). Subsequently the continuity of the gastrointestinal tract in the abdominal cavity should be restored and the caudal portion of the graft should be anastomosed to the stomach. The reconstructive surgery is complete when the cephalic segment of the graft is anastomosed to the cervical esophagus.

The advantageous points of this reconstructive modality include the possibility of obtaining the longest graft of all previously described variants using the right colon provided the above conditions concerning blood supply to the mobilized graft are fulfilled. Another advantage of the presented modality is the isoperistaltic position of the graft, what has a beneficial effect on its further functioning as a replacement esophagus (Fig. 15, 16). The only disadvantage is theoretically much more difficult surgical technique in comparison to previously described variants.



**Figure 15** Radiogram of a replacement retrosternal oesophagus from the right colon on left colic vascular pedicle in an isoperistaltic position. A-P projection



**Figure 16** Radiogram of a replacement retrosternal oesophagus from the right colon on left colic vascular pedicle in an isoperistaltic position. Lateral projection

#### 4. Esophageal reconstructions using the left colon

The presence of advantageous vasculature systems in the right and left halves of the colon as well as efficient arc of Rioloan provide opportunities of using the left colon to create a pedicled esophageal graft in the following ways:

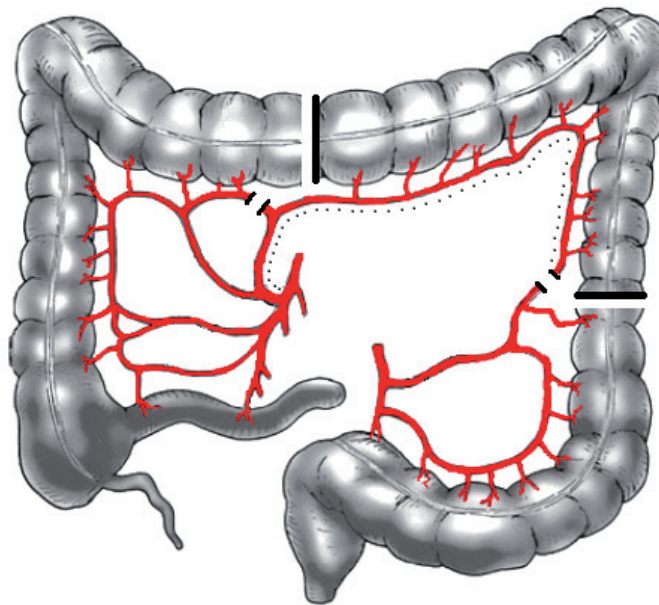
- from the left colon on the middle colic vascular pedicle in an antiperistaltic position of the graft



- from the left colon on the left colic vascular pedicle in an isoperistaltic position of the graft
- from the left colon on the left colic vascular pedicle in an antiperistaltic position of the graft

#### 4.1. The technique of construction of an antiperistaltic graft from the left colon on middle colic vascular pedicle

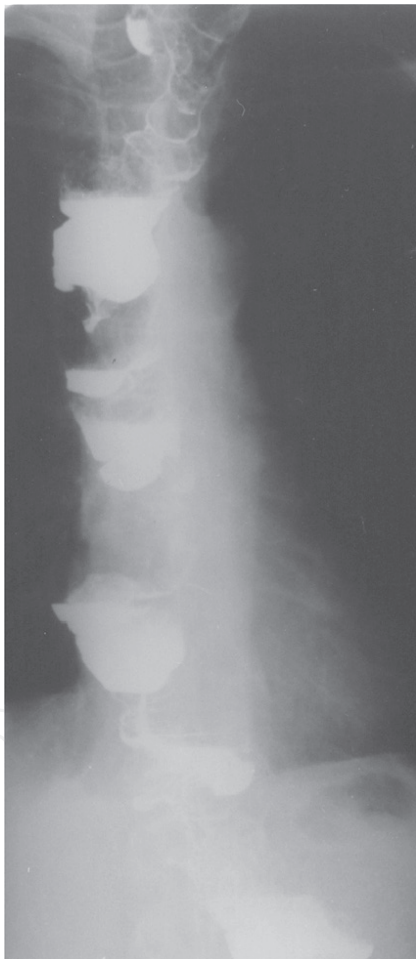
An adequate vascular system in the left colon as well as well developed arc of Rioloan provide an opportunity to use this segment of colon to construct an antiperistaltic graft pedicled on middle colic vessels.



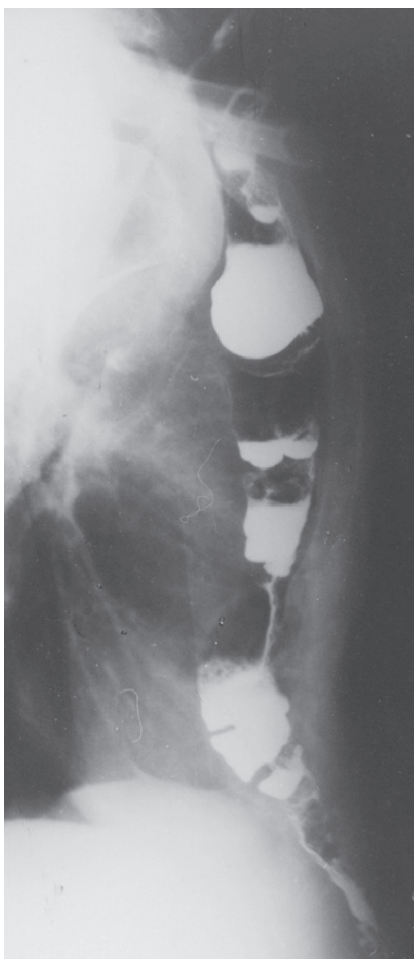
**Figure 17** Diagram of mobilization of a left colon graft on middle colic vascular pedicle in an antiperistaltic position

The surgical technique is as follows. The abdominal cavity is opened through the upper mid-line incision passing by the umbilicus. Next the left colon is mobilized and the biological trial of vascular efficiency is performed. For this reason ligaments of the left flexure of the colon are transected. The left colon together with its vasculature is separated from the posterior abdominal wall as far as the site where the left colic vessels branch off the main trunk of the inferior mesenteric vessels. Next the greater omentum is isolated and the biological trial is performed. The ascending branch of the left colic vessels are clamped with hemostatic forceps nearby ramification of the main trunk into the ascending and the descending branches. Next clamp forceps are applied on the arch between the middle colic and right colic vessels. If the blood supply to the colon is unaffected, mobilization of the graft from the left colon on middle colic vessels may proceed (Fig. 17). The previously clamped vessels should be ligated and transected. In order to obtain a straight graft, the transverse mesocolon is incised radially, terminating the incision 2-3 cm away from the arc of Rioloan. The transverse colon is transected beyond the ramification of

the middle colic vessels. The afferent stump of the transverse colon is closed tight, and the efferent stump, which will form the caudal part of the graft, and will be anastomosed to the stomach, is closed with temporary sutures. In order to determine situationally the site of transection of the descending colon, it should be remembered that the length of graft is the length of its vascular pedicle. The length of the pedicle may be measured approximately using a long thread which measures the length from the stomach angle to the angle of the mandible on the left side of the neck. When the needed length of the pedicle is approximated in this way, the same thread may be used to determine the site of transection of the descending colon by measuring the distance from the region of the middle colic vessels trunk, and, further on, along the arc of Riolan and along the ascending branch of the left colic vessels. Both stumps of the transected descending colon are closed tight with manual sutures, or stapled. The proximal stump of the descending colon will create the cephalic part of the graft. Thus the left colon graft pedicled on the middle colic vessels is constructed. The graft will be in antiperistaltic position.



**Figure 18** Radiogram of a replacement retrosternal oesophagus from the left colon on middle colic vascular pedicle in an antiperistaltic position. A-P projection



**Figure 19** Radiogram of a replacement retrosternal oesophagus from the left colon on middle colic vascular pedicle in an antiperistaltic position. Lateral projection

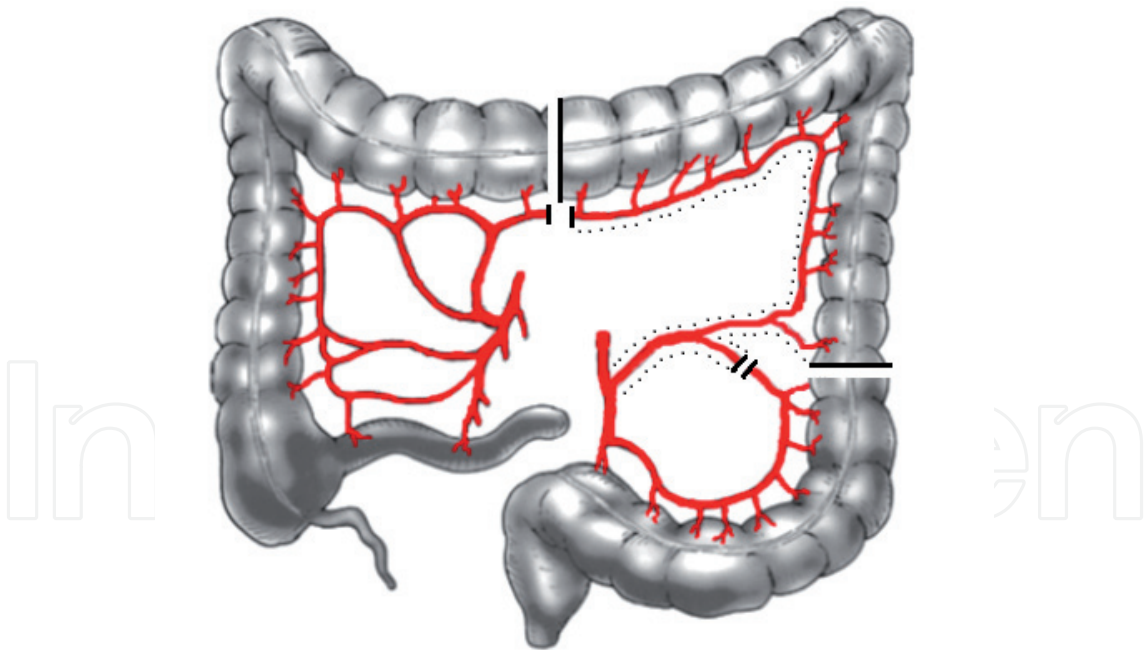
Having constructed the retrosternal canal in a mode described previously, the graft is passed beyond the stomach and through the canal. The descending colon is exposed on the neck, and

distal, caudal part of the graft, formed by the transverse colon, remains in the abdominal cavity to be anastomosed to the stomach. For safe, tensionless restoration of the continuity of the gastrointestinal tract, the hepatic flexure of the colon is mobilized and the colon stumps remaining after mobilization of the graft are anastomosed. Anastomosis of the distal, caudal part of the graft to the stomach terminates the reconstructive surgery. The last stage includes anastomosis of the esophagus with the colon pulled onto the neck. Using the end-to-side anastomosis of the esophagus with the lateral wall of the colon, the anastomosis lumen is wide enough to have a beneficial effect on the function of the antiperistaltic esophageal reconstruction (Fig. 18, 19).

The main advantage of this surgical modality is a relatively simple surgical technique, provided the adequacy of circulation has been evaluated accurately. On the other hand, antiperistaltic position of the graft may be its less advantageous feature, which may slow down the passage of the content through the replacement esophagus.

**4.2. The technique of construction of an isoperistaltic graft from the left colon on left colic vascular pedicle**

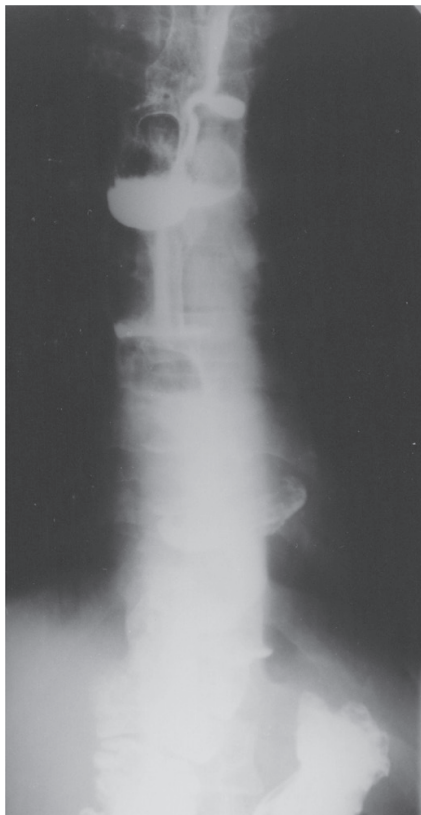
Taking advantage of adequate vasculature in the left colon, finding a long trunk of the left colic vessels, the arc of Riolan and the presence of long, well developed anastomoses between the left colic vessels and sigmoid vessels an isoperistaltic graft with left colic vascular pedicle may be constructed.



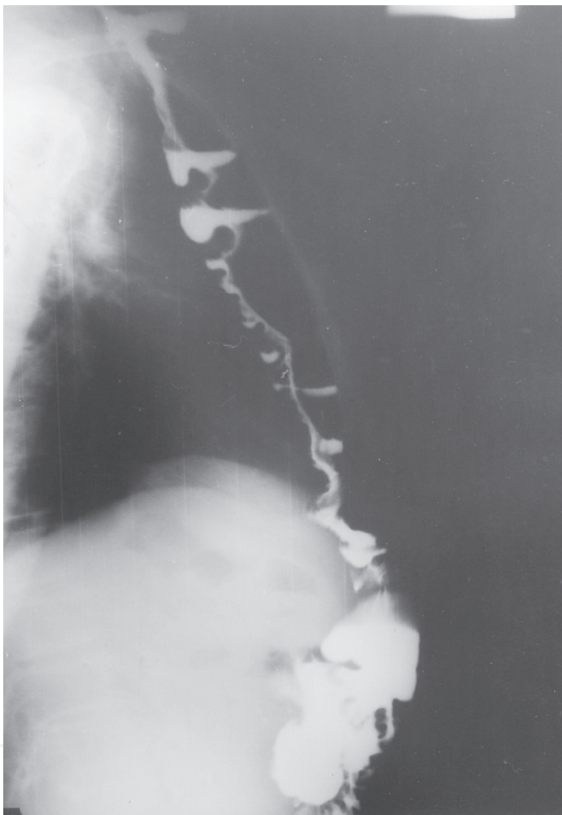
**Figure 20** Diagram of mobilization of a left colon graft on left colic vascular pedicle in an isoperistaltic position

The applied technique is as follows. The abdominal cavity is opened in a routine manner through an upper midline incision passing by the umbilicus. Thorough evaluation of topography of the left colon vasculature may be performed after its full mobilization and separation of the greater omentum. If the macroscopic picture of vasculature presents favourably in the

aspect of graft mobilization, a meticulous trial of the efficiency of the left colic vessels should be performed. The arch joining the middle colic vessels and the left colic vessels as well as the arch joining the left colic vessels and the sigmoid vessels are clamped with hemostatic forceps. In this way the arterial blood supply and the venous blood flow in the left part of the colon are carried out through the left colic vessels alone. A positive biological trial entitles to mobilize the graft. The previously clamped arch of the middle colic vessels should be ligated and transected close to the ramification of the main trunk. The transverse mesocolon should be incised radially, what straightens the graft and facilitates its further mobilization. Next the vascular arch joining the left colic vessels with the sigmoid vessels, the transverse colon, and the descending colon are ligated and transected. The stumps of the transected colon are closed tight by means of a surgical stapler, or a manual suture. In this way an isoperistaltic graft from the left colon on left colic vessels pedicle is mobilized (Fig. 20).



**Figure 21** Radiogram of a replacement retrosternal oesophagus from the left colon on left colic vascular pedicle in an isoperistaltic position. A-P projection



**Figure 22** Radiogram of a replacement retrosternal oesophagus from the left colon on left colic vascular pedicle in an isoperistaltic position. Lateral projection

Subsequently the graft is passed beyond the stomach and placed in the retrosternal canal. The proximal part of the graft, i.e. the transverse colon creates the cephalic part of the replacement esophagus will be anastomosed to the cervical esophagus. The last stage of the reconstructive abdominal surgery includes anastomosing the remaining proximal colon with distal part of the sigmoid colon and the caudal part of the graft with the anterior wall of the prepyloric stomach. Cervical anastomosis and closing the neck and abdominal layers is the last stage of the whole reconstructive surgery.



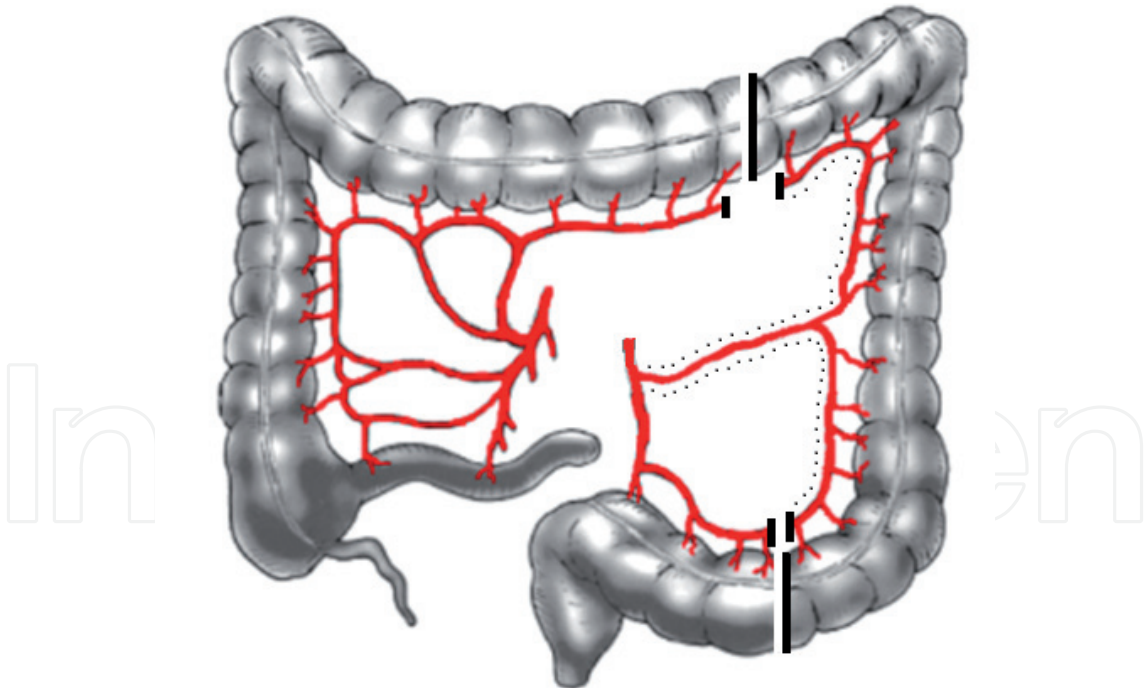
Advantages of this modality include isoperistaltic position of the graft, its straight course in the retrosternal canal, as well as definitely narrower lumen in comparison to the grafts formed from the right colon (Fig. 21, 22).

The fact that in some cases the trunk of the left colic vessels may be well developed, but turns out to be too short to produce a long enough graft which would reach the neck is a disadvantage of this type of reconstructive surgery.

**4.3. The technique of construction of an antiperistaltic graft from the left colon on left colic vascular pedicle**

Choosing this modality to construct a pedicled graft, the architecture of vasculature in the left colon and proximal sigmoid colon must be evaluated exceptionally meticulously, as this method is possible only in such cases in which the main trunk of left colic vessels (arteries and veins) is very long, the descending branch is well developed, exceptionally long, and at the same time it creates firm and efficient anastomoses with the sigmoid vessels.

The surgical technique resembles this described in the previous chapter. The differences include an antiperistaltic position of the graft and the left colic vessels pedicle. Thus in order to obtain an adequately long graft, it is almost always necessary to use the left colon with a proximal segment of the sigmoid colon. Accurate evaluation of the length of the vascular pedicle is decisive for success in obtaining such a graft.



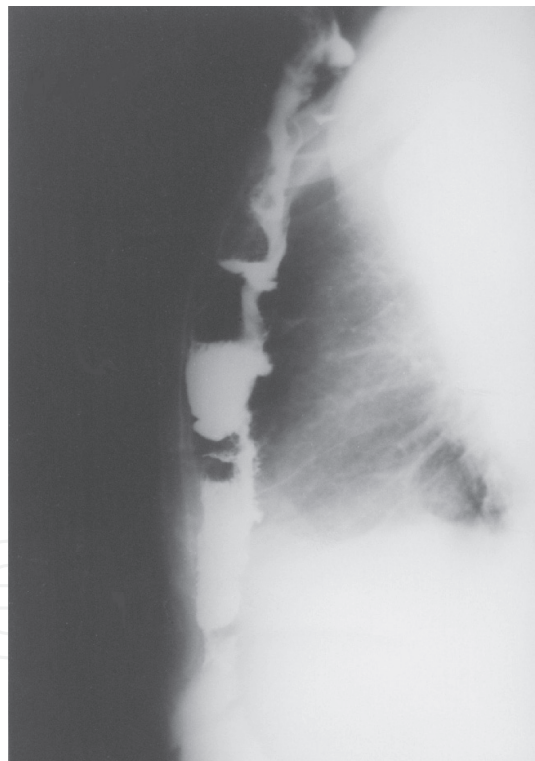
**Figure 23** Diagram of mobilization of a left colon graft on left colic vascular pedicle in an antiperistaltic position

If the vascular system is considered adequate, the left colon should be mobilized and a thorough intraoperative biological trial of vascular efficiency should be performed in order to confirm once again pertinence of the choice. Full mobilization of the graft takes place after ligation and transec-

tion at an adequate level of the ascending branch and the descending branch of the left colic artery and vein, and next of the transverse colon and the sigmoid colon (Fig. 23). Thus constructed graft will be antiperistaltic, that is its distal, caudal part, i.e. the descending colon or proximal segment of the sigmoid colon will be anastomosed to the cervical esophagus, while the proximal part, i.e. the transverse colon – to the anterior wall of the prepyloric part of the stomach.

Subsequent stages of the procedure, as described previously, consist in restoring the continuity of the gastrointestinal tract in the abdominal cavity and anastomosing the pedicled colon segment, which was passed through the retrosternal canal, to the cervical esophagus and the stomach.

The surgical technique of this reconstructive modality is not easy. This especially concerns an accurate evaluation of the length of the vascular pedicle. This type of esophageal reconstruction should be reserved to exceptional cases – with inadequate vascular system in the right colon, precluding reconstruction by means of another and easier method. Moreover, it is not recommended for surgeons with little experience in reconstructive procedures. Antiperistaltic position of the graft may also be considered disadvantageous. Advantages of this surgical modality include the graft's straight course in the retrosternal canal, as well as a definitely narrower lumen in comparison to right colon grafts (Fig. 24).



**Figure 24** Radiogram of a replacement retrosternal oesophagus from the left colon on left colic vascular pedicle in an antiperistaltic position. Lateral projection.

Presenting the above described esophageal reconstructions with the colon, important technical details as well as modes of choosing individual reconstructive modality with the use of right or left colon were described. Also, advantages and disadvantages of individual modalities were presented, taking into account functions the replacement esophagus has to perform.

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